

5

Science Standard  
5.3.b.



# Changing States: Water, Natural Systems, and Human Communities

## **California Education and the Environment Initiative**

Approved by the California State Board of Education, 2010

### **The Education and the Environment Curriculum is a cooperative endeavor of the following entities:**

California Environmental Protection Agency  
California Natural Resources Agency  
Office of the Secretary of Education  
California State Board of Education  
California Department of Education  
California Integrated Waste Management Board

### **Key Leadership for the Education and Environment Initiative:**

**Linda Adams**, Secretary, California Environmental Protection Agency  
**Patty Zwarts**, Deputy Secretary for Policy and Legislation, California Environmental Protection Agency  
**Andrea Lewis**, Assistant Secretary for Education and Quality Programs, California Environmental Protection Agency  
**Mark Leary**, Executive Director, California Integrated Waste Management Board  
**Mindy Fox**, Director, Office of Education and the Environment, California Integrated Waste Management Board

### **Key Partners:**

Special thanks to **Heal the Bay**, sponsor of the EEI law, for their partnership and participation in reviewing portions of the EEI curriculum.

Valuable assistance with maps, photos, videos and design was provided by the **National Geographic Society** under a contract with the State of California.

### **Office of Education and the Environment**

1001 I Street • Sacramento, California 95812 • (916) 341-6769  
<http://www.calepa.ca.gov/Education/EEI/>

© Copyright 2010 by the State of California  
All rights reserved.

This publication, or parts thereof, may not be used or reproduced without permission from the  
Office of Education and the Environment.

These materials may be reproduced by teachers for educational purposes.



## **Lesson 1**    Evaporation, the Water Cycle, and Human Communities

*California Connections: Salt Farming on San Francisco Bay* ..... 2

## **Lesson 2**    Factors Affecting the Evaporation Rate

None required for this lesson.

## **Lesson 3**    How the Water Cycle Affects Natural Systems

How the Water Cycle Affects Plants and Climate ..... 6

## **Lesson 4**    The Cooling Effects of Evaporation

Keeping Cool ..... 7

Cooling Urban Heat Islands ..... 9

## **Lesson 5**    The Role of Condensation in Natural Systems

Condensation in Natural Systems ..... 11

## **Lesson 6**    Freezing in Natural Systems and Human Communities

Castle Lake Under Ice ..... 12

# Salt Farming on San Francisco Bay



Imagine flying an airplane high over San Francisco Bay. Below you lies the Golden Gate Bridge. Its reddish towers reach from one side of the bay to the other. Next your eye follows the edge of the bay to the south.

You see the salt ponds, hugging the edge of the bay. The colors of the ponds look like a patchwork quilt. Pale greens, deep reds, and many colors in between catch your eye. In these ponds, sunlight, wind, and seawater make one of nature's finest gifts, salt.

## The History and Uses of Salt

The Ohlone people were early California Indians who lived in the bay area. The Ohlone may have been the first to collect salt along the edge of the bay. They scraped the salt out of natural hollows called salt flats. Later, the Spanish *padres* made salt. They delivered it to all of their missions. In 1854, John

Johnson first turned salt harvesting into a business. He sold salt to gold miners in the Sierras. Johnson also sold salt for processing silver, making cheese,

keeping meat safe to eat, preventing hides from rotting, and packing fish.

Humans and other animals need salt. It helps the body get rid of waste, such as



Salt ponds on San Francisco Bay



Salting cans of tuna

carbon dioxide. It also keeps the heart beating smoothly.

Before refrigerators were invented, people used salt to keep food from spoiling. Armies lost wars when they ran out of salt. They had no

way to store meat for their troops to eat. In Roman times, salt was so valuable it was even used for money. Roman soldiers received salt as payment. In many cultures, salt is a symbol for purity and goodness. Some California Indian tribes use salt to purify the ground before their ceremonies.

The salt from the San Francisco Bay has many uses. Food packing houses use it in cans of California tomatoes. Cheese factories use it in their recipes. Potato chip factories salt their chips

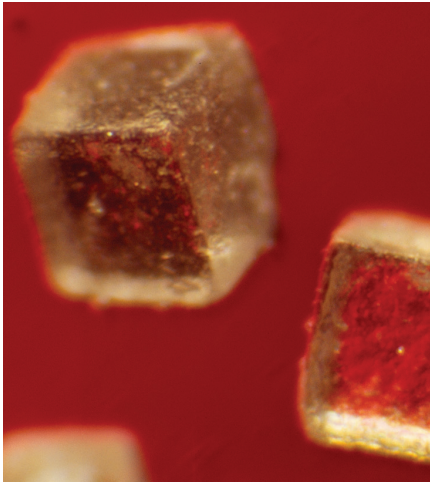
with it. Grocery stores sell salt to cooks, who use it to make food taste better. Some is used in soft water conditioners. During the winter, the State of California spreads salt on mountain highways to keep them free from dangerous ice and snow.

### Salt Production

Today, salt producers use three different methods. The newest method uses steam to separate the salt from salty water. Another method involves mining salt from below Earth's surface,



Salt company worker



Salt grains magnified 25 times

where ancient oceans left salt deposits. The oldest way to produce salt is by solar evaporation. This method has been used for centuries on the edge of San Francisco Bay.

How do the sunlight, wind, and seawater come together to make salt? The Sun shines on the salt ponds and heats the seawater. This heat turns the water into vapor, or steam. Water becomes vapor through the process called evaporation. Much of the water evaporates, but the salt remains behind. The small amount of water left in the ponds, called brine, is very salty. These ponds are called concentration ponds.

Workers keep the brine moving to the next pond, where it becomes even saltier. When the salinity is over 25 percent, the workers move the brine to a crystallizing pond.

Evaporation continues as the Sun warms the crystallizing pond, removing the rest of the water from the brine. A thin film of salt soon forms on top. As salt crystals attach to this film, they become very heavy. They drop to the bottom of the pond or cling to the sides. Eventually, the layer of salt on the bottom builds up until it is 4 to 10 inches deep. When the layer is thick enough, workers scrape the salt “crop” from the bottom with a special plow. Workers then wash the salt and put it in a large pile to drain. It is dried in ovens called kilns or left to dry in large, flat beds.

Remember how red some of the salt ponds were when you looked at them from your airplane? Tiny bacteria called halobacteria are responsible for this color. They love salt. The

halobacteria manufacture a red pigment similar to the color found in tomatoes, red peppers, and fall leaves. Do not worry, the salt you buy in the store is safe to use! Halobacteria are not harmful to humans. Besides, the salt you eat has been cleaned until it is bright white.

### The Future of the Salt Ponds

In 2003, the company that owns the salt ponds by San Francisco Bay sold 16,500 acres to the State of California. The company will work with the state to turn the ponds back into a healthy tidal marsh. Shorebirds, including the snowy plover, least tern, and California light-footed



Endangered California light-footed clapper rail

clapper rail, will then have a new place to land.

The process of restoring the marsh will take some time. Many people work on the project. They break the levees that hold water in the salt ponds. Bay water then washes the salt back into the bay. People also plant native plants that provide habitat for animals in the marsh. These actions will help restore the marshes.

### Making Solar Salt

Try to make solar salt on your own! In place

of concentration and crystallization ponds, use wide-mouthed glass jars. In place of the salty water from the San Francisco Bay, use your own “seawater.”

First, pour two cups of water into a glass jar. Add one cup of salt and stir the water and salt mixture with a spoon. Let the jar sit for 10 minutes until the extra salt settles on the bottom. Carefully pour the water into another wide-mouthed jar. Throw the extra salt away, or use it in some soup!

Set the jar outside where it can get some sunlight and air. Make sure that no rain or water from sprinklers dilutes the salty water. Let the jar stand for a few days. At first, you will notice a thin film of tiny crystals forming on top of the water. As more water evaporates, larger crystals will form on the film. Some of these crystals will become so heavy they will sink to the bottom. Others will cling to the sides. This is exactly what happens in the crystallizing ponds.

When enough crystals fall to the bottom of the jar, carefully pour out the water. You might notice that this water is a lot less salty than when you started. Most of the salt has separated from the water during the process of evaporation. Now you can scrape the bottom and sides of the jar. Be careful, because the little salt crystals are very strong, and you may break the glass! Ask your teacher or another adult to help you with this step. Congratulations—you have made your own salt!



Habitat restoration at San Francisco Bay salt marsh

# How the Water Cycle Affects Plants and Climate

Plants need water, nutrients, and sunlight to live. When there is enough sunshine and water, the stomata of plants open. The stomata take in carbon dioxide (CO<sub>2</sub>) from the air that the plants need to photosynthesize. Water also transpires from the open stomata. As plants transpire, more water and nutrients are pulled up from the soil. As long as there is enough water in the soil, plants transpire more when it is warm than when it is cool. In tropical areas where there is plenty of water and it is warm year-round, the conditions are right for many plants to live and grow.

Having this many plants in one place influences the local climate. During transpiration, plants take up huge amounts of water from the ground. About 90% of the water they take up evaporates into the air as water vapor. The water vapor in the atmosphere condenses to form clouds. Then, if conditions are right, the water will return to Earth as rain.

Scientists have been studying rainforests for many years. More plants grow in rainforests than anywhere else in the world. A huge amount of water evaporates into the air above them. This water forms clouds in the atmosphere and then comes back to the rainforest as rain. About half of the rainfall in the Amazon tropical rainforest comes from

local evaporation. The other half comes from clouds that form over the oceans.

In one study, scientists observed the water cycle in the Amazon rainforest and found that about 20% of the rain that fell from clouds over the rainforest evaporated back into the air before it ever reached the ground! Luckily, for all of the plants and other living things in the rainforest, the rest of the rain does reach the ground. Plants take it up and transpire it back into the air. One-half of the rainfall goes directly back into the air as water vapor from transpiration and evaporation. The other 50% runs off into rivers.

Rainforests also occur along the central and northern California coast. Our coast redwood forests are temperate rainforests. They are cooler than tropical forests, like the Amazon, so the amount of water vapor they put into the air is less. Still, they receive more than 50 inches of rainfall a year. About 10% of that rain comes from water that transpired and evaporated locally.



Tropical plant

# Keeping Cool

When you get out of a swimming pool on a windy day, what happens? You may get goose bumps and start to shiver. Water evaporates from your skin. As it does, it takes heat away from your skin, making you feel much cooler. Wind speeds up evaporation, so you feel even colder when the wind is blowing.

Humans have a built-in cooling system. When you exercise really hard, your body starts to sweat. The sweat evaporates from your skin. As it does, it takes heat energy away from your body. This cools you off. If you want to get cooler faster, you can fan yourself to increase the rate of evaporation.



Dog panting

Dogs have no sweat glands. To get rid of extra heat, they pant. The only way they can cool off is by evaporating water from their mouths. Cats lick themselves to stay cool. As the saliva evaporates from their fur, they cool off.

Plants also have a way to stay cool. During transpiration, water evaporates from leaves.

More than 90% of the water that plant roots take in evaporates into the air through transpiration. Evaporation of this water helps keep plants cool by taking heat away from the surrounding environment. This is very important in places where there are many plants. If evaporation did not cool the surrounding air, many tropical rainforest areas would be too hot and organisms could not survive there.

Think of walking into a forest on a hot, sunny day. The air temperature in the forest is usually several degrees cooler. This cooler temperature is partly because of shading and partly because of the cooling effects of evaporation. Actually, about 80% of the cooling effect of the forest is due to transpiration and evaporation. Hot air passes over leaves of the plants in the forest. The water that is evaporated

## Keeping Cool

Lesson 4 | page 2 of 2

cools the surrounding area. Cooling by evaporation can lower the temperature of an area by as much as 9° F (5° C). Many plants and animals live in or near forests,

where it stays cooler on hot summer days. They depend on transpiration and evaporation to keep their habitats cool.



California rainforest

# Cooling Urban Heat Islands

Think of an asphalt road on a hot sunny day. You would not try to walk barefoot on it. You would burn your feet! The asphalt absorbs a lot of heat from sunlight. If you were barefoot, you would head for a grassy area instead. Grass is much cooler. Walking under shade trees is even cooler.

As cities grow, they get hotter. More and more buildings, roads, bridges, and other structures cover the landscape. These structures are made of concrete, brick, and asphalt. All of these man-made materials take in heat. They get very hot. They also give off heat, so the air around them gets hotter, too.

Large cities are “urban heat islands” because they are much warmer than the areas around them. On summer days, the air in a city can be 5–9° F hotter than the air in nearby rural areas. Although they cool down after sunset, the temperature of a city at night can be 10° F warmer than the areas around it.



City trees and skyline

What can be done to cool down these urban heat “islands?” Planting trees can help cool cities. Trees transpire and the evaporation of the transpired water takes heat energy from the air around the trees as it changes from liquid water into water vapor. This cools the air. One tree with a crown of 30 feet can transpire up to 40 gallons of water in a day. If all that water evaporates, that is a lot of heat energy that can be removed from the air. Trees also cool an area by shading it.

A group of trees in a park or other place in the middle of the city is not a strange sight. Trees planted together grow better. They protect each other from drying wind

and sun. Besides creating a nice place to rest and play, these trees naturally cool the nearby neighborhoods. Evaporation in an area around several trees can cool the temperature of the surrounding air by 10–15° F on a hot summer afternoon.

In some cities, rooftop gardens are used to help bring down the temperature. On a sunny summer day, the roof of a building can reach 175° F (79° C). Plants can help keep the surface of a roof and the surrounding air cooler. The inside of the building stays cooler, too. Scientists say that if half of the flat roofs in New York City were “greened,” the average temperature in the city would go down 1.4° F (0.6° C).

# Condensation in Natural Systems

Dew is a very important source of water for many plants and animals, especially in deserts. The smooth and spread-out branches of the Palo verde tree and the downward-pointing needles of a cactus are places where water vapor condenses in the cool early mornings.



Palo verde tree

The dew that collects on these plant parts runs or drips down to the plant base, making the soil moist. Many desert animals are more active at night than in the day, so they are able to drink the dew before it evaporates in the sunlight.

People that live in dry areas have collected dew for drinking water for centuries. By using “dew harvesters,” farmers in areas that are very dry can collect enough water to grow crops. Collecting dew is not hard; in the early morning when condensation has taken place (dew point), take a clean bandana and tie it loosely around your ankle. Then walk slowly through a grass field, letting the bandana touch the wet grass as much as possible. Soon, the bandana (and your shoes) will be saturated with fresh water. Carefully squeeze the dew from the bandana into a container and you have water to drink!



Cactus

# Castle Lake Under Ice

Castle Lake is high in the mountains of northern California. The lake is 5,435 feet above sea level. Mountain glaciers carved the lake out of granite rock into the shape of a bowl.



Castle Lake under ice

California Indians named the lake the Castle of the Devil. They believed an evil spirit lived in the lake because of the scary sounds coming from the lake on cold winter nights. The sounds can still be heard today. However, today we know that these moans and groans are not coming from an evil spirit. They come from cracking ice.

As water freezes, it expands. Sometimes the expanding ice is locked in by other ice.

The newly forming ice has no room to expand. It pushes against and cracks the ice around it. On cold still nights, the eerie sounds of cracking ice can travel all across the lake.

The cracking ice may sound dangerous, but the ice is actually doing a good thing. It forms a lid over the lake that keeps living things in the lake from freezing.

The ice cover keeps the water temperature of the lake warmer than the air above

the ice. The water just under the ice stays at 32° F (0° C). Water at the bottom of the lake is warmer. It stays at 39° F (4° C).

Animals can survive in the cold water under the ice. Lake animals, such as fish and amphibians, are cold-blooded. When the lake freezes over, their body temperatures drop and they become very sluggish. For example, the Cascades frog hibernates in mud at the bottom of Castle Lake. Lake trout survive the winter in the deeper, warmer water under the ice on the lake, burning the energy they have stored up in their bodies.

Other animals that live around the lake, such as river otters, go under the ice to catch the fish for food, so that they can survive the cold winter, too.

Green algae can also survive in cold water under the ice. These algae are an important part of the community of living things in the lake. They serve the same function as plants on land. That is, they carry on photosynthesis. They use the Sun's energy to make food. As they do so, they also produce oxygen that they release into the water. All of the other living things in the lake depend on algae for food and oxygen.

Algae depend on the protective cover of ice to keep them from freezing. Once snow covers the ice, not enough light can get through the ice for photosynthesis. The algae must use food they have stored in their cells to survive. Because the water is so cold, they burn their stored food very slowly. They slowly sink to the bottom of the

lake where the water is warmer.

In spring, the Sun melts the ice, and the water at the bottom of the lake rises and brings nutrients up to the top. Water and nutrients are then mixed throughout the lake. With sunlight and nutrients throughout the water, the algae begin to grow quickly. Soon, there is plenty of food for all the other living things in the lake.



River otter with fish







California STATE BOARD OF  
EDUCATION

---

## California Education and the Environment Initiative